



Advanced Exploration Systems

NASA Advisory Council

July 31, 2013

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Advanced Exploration Systems (HEOMD)

- Advanced development of exploration systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit.
- Demonstrate prototype systems in ground test beds, field tests, underwater tests, and ISS flight experiments.
- Use and pioneer innovative approaches for affordable rapid systems development and provide hands-on experience for the NASA workforce.
- Maintain critical competencies at the NASA Centers and provide NASA personnel with opportunities to learn new and transform skills.
- Infuse new technologies developed by STMD into exploration missions.
- Support robotic missions of opportunity to characterize potential destinations for human exploration.

Summary for FY13

- AES has established 64 project milestones for FY13. Goal is to achieve at least 80%. Projected success rate is 86%.
- AES is developing 11 flight experiments.
- AES is employing 578 civil servants in FY13.

Defining the Combined AES/STP Portfolio



Human Architecture Team:
Design Reference Missions

Strategic Knowledge Gaps:
Guide robotic precursor activities

HEOMD Time Phased Capability Investment Priorities

Strategic Space Technology Investment Plan: used to balance Agency investments

STMD / GCD ETD: Matures component technologies

STMD / TDM ETD: Matures system level technologies

AES Program:
Prototype systems development & testing

Exploration Flight Systems
- Including ISS based Risk Reduction Demonstrations

ETD – Exploration Technology Development
STMD – Space Technology Mission Directorate
GCD - Game Changing Development
TDM - Technology Demonstration Missions

Rapid development and testing of prototype systems and validation of operational concepts to reduce risk and cost of future exploration missions:

➤ **Crew Mobility Systems**

- Systems to enable the crew to conduct “hands-on” surface exploration and in-space operations, including crew excursion vehicles, advanced space suits, and crew egress

➤ **Deep Space Habitation Systems**

- Systems to enable the crew to live and work safely in deep space, including deep space habitats, reliable life support, radiation protection, and fire safety

➤ **Vehicle Systems**

- Systems for in-space propulsion stages and small robotic landers, including nuclear propulsion, modular power systems, lander technology test beds, and autonomous precision landing

➤ **Operations**

- Systems to enable more efficient mission and ground operations, including integrated testing, autonomous mission ops, integrated ground ops, and logistics reduction

➤ **Robotic Precursor Activities**

- Acquire strategic knowledge on potential destinations for human exploration to inform systems development, including prospecting for lunar ice, characterizing the Mars surface radiation environment, radar imaging of NEAs, instrument development, and research and analysis

AES Risk Reduction Timeline



	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20
Deep Space Habitation Capability									
Deep Space Habitat			Mockups						
Air Revitalization (ARREM)		Gnd Testing							
Water Recovery			Gnd Testing						
Life Support						ISS Demo			
Radiation Protection		ISS Demo	EFT1 Demo						
Logistics Reduction									
Fire Safety				Flt Exp	Flt Exp	Flt Exp			
BEAM Inflatable Module				ISS Demo					
Crew Mobility Capability									
EVA Suit			PLSS testing		Trans. to ISS			ISS Demo	
Suitport	Gnd Test								
Habitable Airlock			NBL Test						
Analogs / Integrated Testing									
Vehicle Systems Capability									
Morpheus/ALHAT			Flt Exp						
Modular Power Systems			DSH Pwr Sys						
Nuclear CPS			Fuel Selection						
Operations Capability									
Autonomous Mission Ops			ISS Demo						
Integrated Ground Ops			Gnd Demo	SWORDS Demo					
Avionics & Software									
Additive Manufacturing			ISS Demo						
Communications & Networking		OPALS	DTN						
Robotic Precursors Capability									
RESOLVE (ISRU)									
Resource Prospector Mission			MCR				Flt Exp		
Goldstone Radar		NEA Detection							
Radiation Assessment Detector		MSL Data							
Mars 2020 (ISRU)				PDR					Mars Demo
SSERVI				NEA Research					
Asteroid Redirection Capability									
Asteroid Capture System		MFR							

System Maturation Teams are refining the AES risk reduction strategy

Major FY13 AES Milestones



Nov 2012	Spacecraft Fire Safety: Complete Mission Concept Review and Systems Requirements Review
Jan 2013	Radiation Protection: Complete the Critical Design Review for the EFT-1 Radiation Environment Monitor
May 2013	Bigelow Expandable Activity Module: Complete Phase 1 Safety Review
May 2013	Deep Space Habitat: Complete Systems Definition Review for MPLM-based deep space habitat
Jul 2013	Morpheus/ALHAT: Complete KSC flight tests of ALHAT on Morpheus lander to demonstrate autonomous hazard detection and avoidance.
Jul 2013	EVA: Complete assembly and integrated testing of Portable Life Support System 2.0 to validate schematic and packaging concept.
Aug 2013	Habitable Airlock: Test mockup Habitable Airlock with crew in Neutral Buoyancy Facility
Sep 2013	Resource Prospecting Mission: Complete Mission Concept Review.

FY13 Project Milestone Status

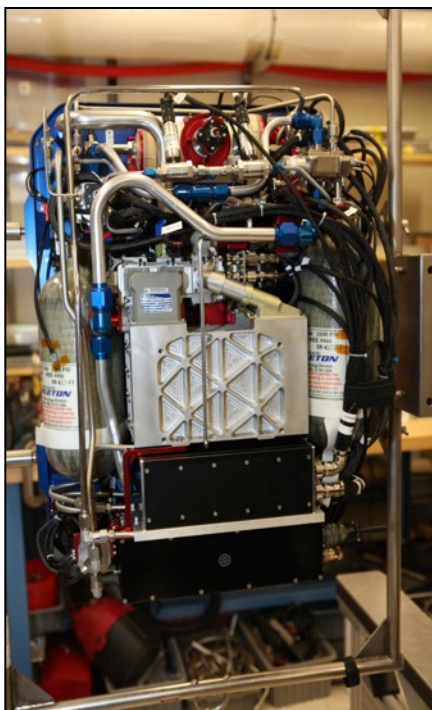


Project	Status
Autonomous Mission Ops	Developing advanced caution and warning system for EFT-1
Spacecraft Fire Safety	Completed MCR & PTR-1
Modular Power Systems	Developed DSH power architecture
Goldstone Radar	Imaged 6 NHATS targets
Radiation Assessment Detector	Measuring radiation environment on Mars surface
Morpheus/ALHAT	ALHAT flight tests slipped due to delays in vehicle assembly.
Integrated Testing	Developing test plans
Habitable Airlock (MMSEV)	Test of pressure control system may slip into FY14
Deep Space Hab	Integrating systems in MPLM mockup
EVA	Completed PLSS 2.0 assembly. Testing delayed.
Water Recovery	Testing Cascade Distillation System and calcium limiter
Air Resource Recovery & Environmental Monitoring	Cycle 2 testing of ISS-derived air revitalization components delayed due to budget reduction
Radiation Protection	Completed assembly of radiation monitors for EFT-1

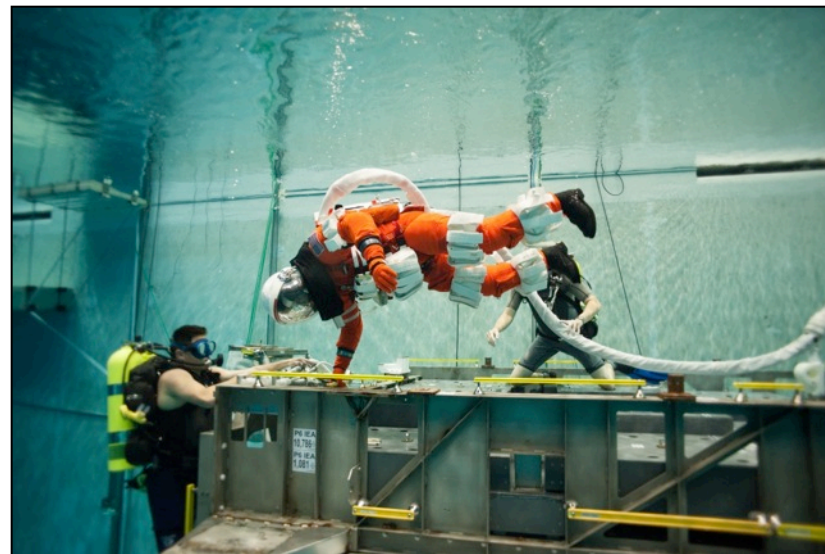
Project	Status
Logistics Reduction	Gen 2 Heat Melt Compactor fab delayed due to budget reduction
Integrated Ground Ops	LH2 propellant loading demo delayed due to budget reduction
RESOLVE/RPM	Seeking partner to develop lander
Nuclear CPS	Graphite composite fuel element fab delayed due to budget reduction
SSERVI (NLSI)	Issued CAN to select new teams
Lunar Mapping & Modeling	Developing education modules; Supporting RESOLVE mission
BEAM	Signed contract with Bigelow. Completed burst pressure test.
Core Flight Software	Implementing CFS on fault tolerant computing architectures
Avionics Architectures	Defining a reference architecture for common avionics
Delay Tolerant Networking	Demonstrated DTN on ISS for teleoperation of robots
KaBOOM	Installed 3 antennas at KSC and completed functional tests
Additive Manufacturing	Developing 3D printer for ISS demo. Completed SRR.
Composites	Fabricated 1/6-arc fairing panel
OPALS	Completed environmental testing

Recent Accomplishments

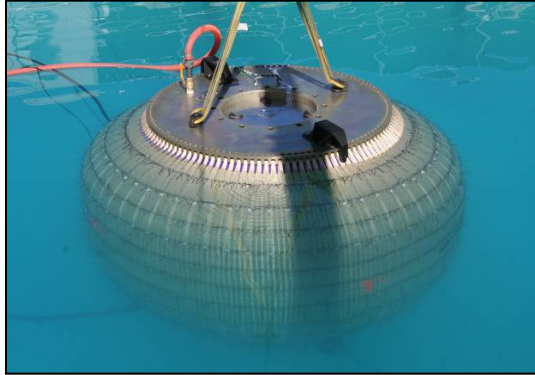
Crew Mobility Systems Domain



EVA: Completed assembly of the Portable Life Support System (PLSS) 2.0. This is the first new PLSS to be developed since the Shuttle EMU was introduced in 1981. The PLSS 2.0 incorporates new technology components developed by the Space Technology Mission Directorate for CO₂ removal, suit pressure regulation, thermal control, and energy storage.



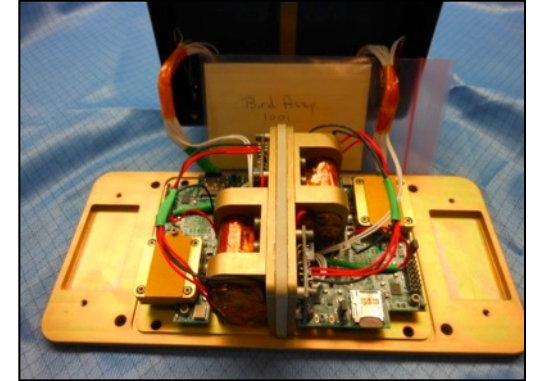
EVA: Tested Modified ACES suit in Neutral Buoyancy Lab to evaluate its potential use for Orion contingency and Asteroid Redirect Mission EVAs.



BEAM: Signed \$17.8M contract with Bigelow Aerospace to develop inflatable module for demonstration on ISS in 2015. Completed burst test to 8x operating pressure.



Life Support: Completed integrated chamber tests of ISS-derived Carbon Dioxide Removal Assembly, Trace Contaminant Control System, Sabatier reactor, and Oxygen Generation Assembly



Radiation Protection: Completed assembly of the Battery-Operated Independent Radiation Detector (BIRD) Flight Unit #1 for EFT-1 mission.

Recent Accomplishments

Vehicle Systems Domain



Morpheus: Completed first tether test of new 1.5B vehicle. Demonstrated stable hover and in-flight switching from the primary IMU to the backup IMU. ALHAT components are being installed.



ALHAT: Completed helicopter flight tests of integrated ALHAT system at KSC to demonstrate hazard detection and safe landing site selection.



Nuclear Propulsion: Set up extruder at ORNL and conducted trial runs to fabricate graphite composite fuel elements.

Recent Accomplishments Operations Domain

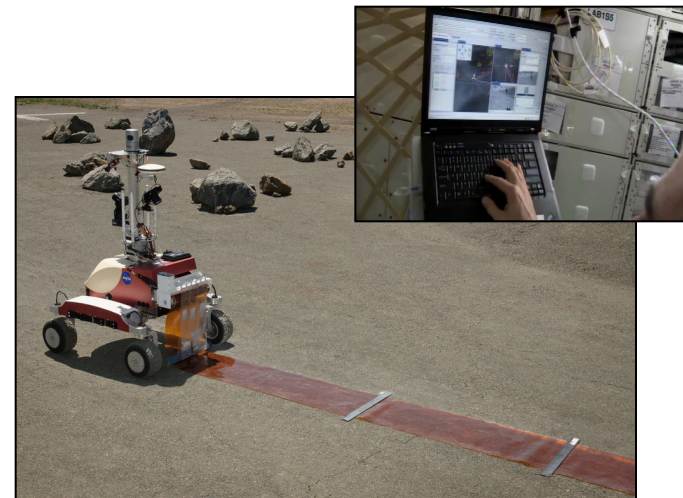


Ka-Band Objects Observation & Monitoring (KaBOOM): Completed installation of three 12 m antenna dishes at KSC



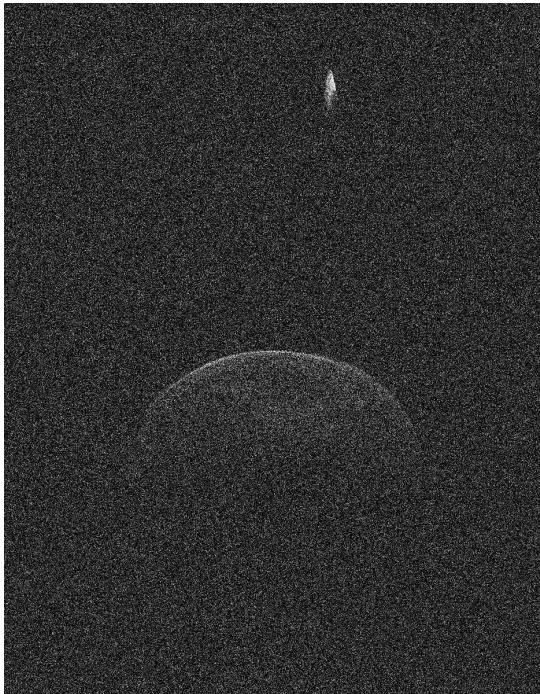
Integrated Ground Ops: Installed a 33,000-gallon LH2 tank (left) and 2,000-gallon LOX tank (right) at KSC to demonstrate zero boil-off cryogenic propellant storage, and autonomous control of propellant loading. Partnership with US Army's SWORDS nanosat launcher program.

DTN: Astronaut onboard ISS demonstrated teleoperation of rover on the ground using DTN protocol. Simulated roll out of film antenna for lunar farside radio telescope.

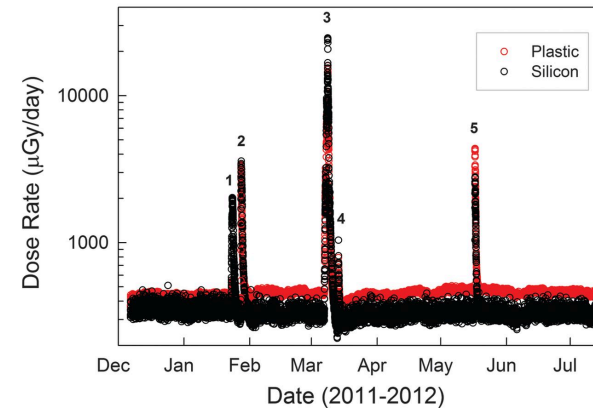


Recent Accomplishments

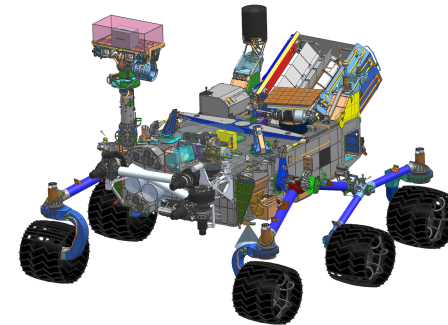
Robotic Precursor Activities Domain



Goldstone Radar: Characterizing potential targets for Asteroid Redirect Mission. Discovered moon around asteroid 1998 QE2 during its closest approach (0.04 AU) on May 31.



Radiation Assessment Detector: Operating for over 320 sols on Mars. Dose rate data acquired during trip to Mars were published in the May 31 issue of the journal *Science*.

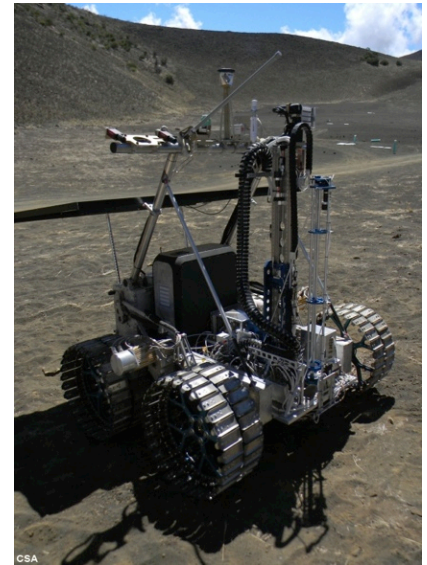


Mars 2020: Partnering with SMD and STMD to develop an in-situ resource utilization payload to demonstrate oxygen production from the Martian atmosphere.

Resource Prospector Mission



- The Resource Prospector Mission (RPM) is being jointly developed by NASA and the Canadian Space Agency to prospect for ice in the polar regions of the Moon. RPM is targeted for launch in 2018.
- Utilizing lunar resources to produce oxygen and propellants could enable new mission architectures for human exploration.
- RPM consists of a rover, a subsurface sampling drill, a small oven to heat regolith samples, and instruments to characterize volatiles.
- Issued RFI on July 2 for NASA-industry partnerships to develop a robotic lunar lander. Potential NASA contributions include technical expertise, test facilities, and hardware or software. Commercial lander could support NASA missions such as lunar resource prospecting and sample return. Responses are due on August 2.
- Mission Concept Review for Resource Prospecting Mission will be held at ARC on September 17. Continuing to work with JAXA on defining a lunar lander concept based on SELENE 2.
- Korea Aerospace Research Institute (KARI) is interested in providing a lunar communications relay for the Resource Prospecting Mission on their 2017 pathfinder orbiter.

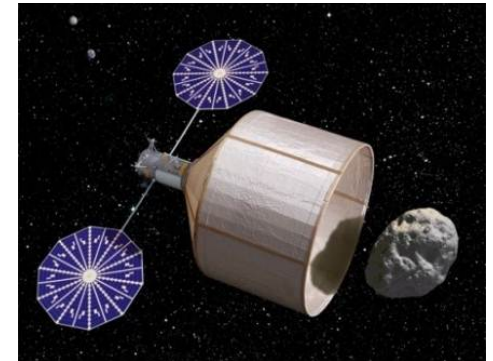


Field test in Hawaii

Asteroid Redirect Mission (ARM) Status



- AES is supporting ARM by developing the Asteroid Capture System and crew systems for asteroid exploration.
- Issued RFI on June 18 to gather ideas from the broad community on ARM system concepts, augmenting NEA observation capabilities, and partnering approaches for planetary defense. Received 402 responses, with 38 per cent submitted by the general public.
- Established multi-Center team led by JSC to analyze alternate concepts for the Asteroid Capture System. Two alternate concepts are being studied: tendon-actuated manipulators, and an inflatable structure with internal bristles to slow the asteroid's rotation.
- Alternate Asteroid Capture System concepts and summary of RFI responses were presented at Mission Feasibility Review on July 30. MFR results will be used to determine budget and workforce allocations for FY14.
- Planning public workshop at Lunar and Planetary Institute on Sept. 30 – Oct. 2 to synthesize inputs from RFI.
- A panel session on ARM will be held at the AIAA Space 2013 Conference in San Diego on September 11.



Asteroid Capture System



Modified ACES suit for asteroid EVA

AES Flight Experiments in Development



- **ISS**

- Additive Manufacturing (2014)
- Autonomous Mission Operations (2014)
- BEAM: Bigelow Expandable Activity Module (2015)
- Delay Tolerant Networking (2012)
- EVA Suit Demo (2019)
- Medipix Radiation Sensors on ISS (2012)
- OPALS: Optical Payload for Lasercom Science (2013)
- Spacecraft Fire Safety (2015)

AES is supporting
ISS Strategic
Implementation Plan
with technology
demonstrations

- **EFT-1**

- Advanced Caution and Warning System (2014)
- Radiation Environment Monitors (2014)

- **Mars**

- Radiation Assessment Detector (2012)

- **Formulation**

- EM-1 Secondary Payloads (2017)
- Resource Prospecting Mission (2018)
- Mars 2020 Oxygen Production from Atmosphere Demo (2020)

Active

- EVA Portable Life Support System
- Advanced Life Support
- Radiation Protection
- Modular Power Systems
- Autonomous Systems for propellant loading
- Additive Manufacturing Demo on ISS
- DTN for ISS Telerobotics
- Instruments for Resource Prospecting Mission

Formulation

- Mars 2020 atmospheric ISRU demonstration
- Composite structures for SLS upper stage
- Asteroid Redirect Mission

- AES has established 64 project milestones for FY13. Goal is to achieve at least 80%. Several projects will miss their milestones due to sequestration budget reductions. Projected success rate is 86%.
- The AES End-of-Year Review will be held on Sept. 18-20 at ARC to review the progress of all projects in accomplishing their FY13 milestones, and to discuss plans for FY14.
- AES is developing 11 flight experiments for ISS, EFT-1, Mars, and lunar missions.
- AES is collaborating with STMD to infuse advanced technologies into prototype systems.
- AES is supporting the Asteroid Redirect Mission with development of asteroid capture system and crew systems for asteroid exploration.